

## CHAPTER 2

### HEATING LOAD

#### Section I. HEAT TRANSMISSION

##### 2-1. Determining Heat Loss

*a. Heat Transfer.* If two adjacent substances are of unequal temperatures, heat flows from the hotter substance to the colder. Heat transfer may take place by conduction, convection, or radiation. Conduction is the process of heat transfer through a material by the transmission of energy from molecule to adjacent molecule. An example is the passage of heat along an iron bar, one end of which is held in a fire.

Convection is the transfer of heat by either natural or forced motion of a fluid (liquid or gas). An example is the heating of a room by the circulation of air from a space heater. Radiant heat transfer (radiation) is the transmission of heat energy across intervening space by electromagnetic waves. An example is the heating of the earth by the sun. Each of these methods of transfer plays a part in the rate of heat loss of a building. Heat in the air

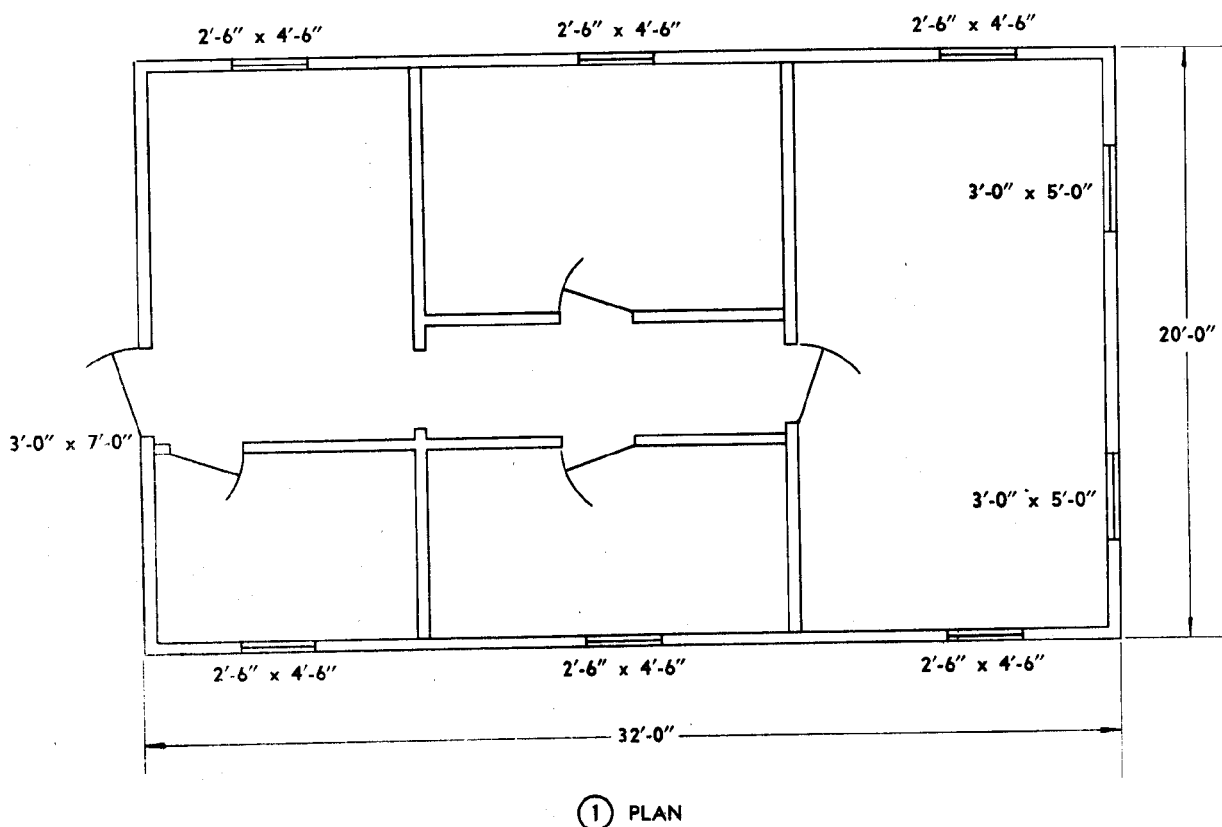


Figure 2-1. Building used in example of heat loss calculation.

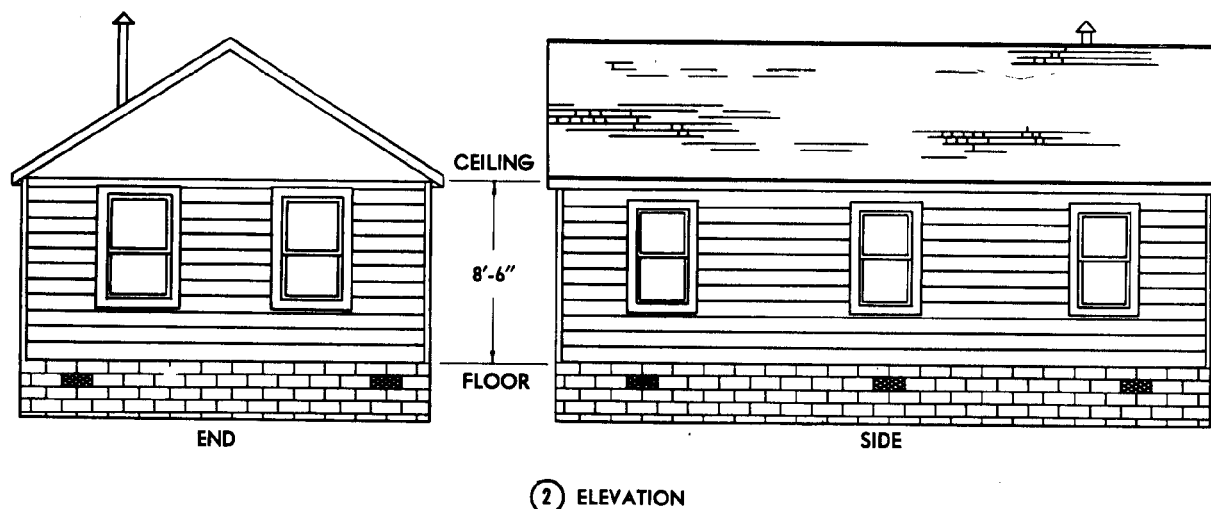


Figure 2-1—Continued.

within the building is carried largely by convection to the walls, roof, and floor enclosing it. It is then conducted through these surfaces to the outside where it is again picked up by air currents and convected away. In addition to artificial means of providing heat within the building, buildings also receive heat from the direct radiation of the sun. However, this radiation is seldom taken into account in determining the quantity of heat needed because heating systems are required to provide sufficient heat on cloudy days and at night.

**b. Method of Heat-Loss Calculation.** The amount of heat needed to maintain temperatures within a heated structure is equal to that lost from the structure by transmission through the walls, glass, doors, floors, and ceilings enclosing it, plus that required to warm up the air which infiltrates through cracks around doors and windows. This rate of heat loss can be calculated from knowledge of the construction and dimensions of the buildings. The heat-loss calculation for the building shown in figure 2-1 is used as an example and is analyzed in *c* below. Calculation values can be found in tables in the appendices in this manual. The basis for the method and use of the data is discussed in paragraphs 2-4 through 2-10.

### c. Calculation for the Example.

Construction Data:		Heat transfer coefficient B.t.u./hr./sq. ft./° F.
Walls:	Clapboard, roofing felt, 1" wood sheathing.	U factor 0.27
Glass:	Single	1.13
Floor:	Single wood floor under composition flooring, space under floor ventilated.	.45
Roof:	Asphalt shingles, 1" wood sheathing, ½" insulating board ceiling.	.23

Infiltration Data:	
Sliding wood sash, not weather stripped	.018 B.t.u./hr./cu. ft./° F.

Temperature Data:	
Inside	70° F.
Outside	0° F.

Heat Loss		Area or Vol.	U factor	Temperature difference	Loss in B.t.u./hr.
Calculation:					
Walls (less glass).	765.5 sq. ft.	0.27	70°	14,468	
Glass	118.5 sq. ft.	1.13	70°	9,373	
Floor	640 sq. ft.	.45	70°	20,160	
Roof	640 sq. ft.	.23	70°	10,304	
Infiltration	5,440 cu. ft.	¾ x .018	70°	5,141	
Total heat loss					59,446

## 2-2. Calculation of Heat Flow Through Building Materials

Heat loss (*Q*) by conduction through the materials making up the enclosing surfaces of a

building is calculated in units of B.t.u. per hour. It is determined by multiplying the area (A) of each different type of material involved times the temperature difference ( $\Delta T$ ) across that material from inside to outside, times the heat transfer coefficient (U factor) for the specific construction:

$$Q = UA\Delta T$$

The heat loss through each type of construction is calculated separately, and the individual losses are added to the losses from infiltration to get the total heat loss of the building. A slight change in the method of calculation is made for concrete floors laid on the ground. The heat loss of such floors varies more nearly with the total length of the outer edge than the area, and the total heat loss is determined by multiplying the perimeter of the floor by a coefficient, selected from appendix E. These heat-loss coefficients are expressed in B.t.u. per hour per linear foot of exposed edge and vary with the outside design temperature. As an example the heat loss from a 25-foot by 40-foot concrete floor without insulation, for an outside design temperature of 0°F., is—

$$60(25 + 40 + 25 + 40) = 7,800 \text{ B.t.u. per hour}$$

## Section II. DESIGN TEMPERATURES

### 2-4. Indoor Temperature

Desired indoor temperatures vary somewhat with the usage of the space, the activity of the occupants, and whether or not there may be additional sources of heat within the space. Table 2-1 lists inside temperatures to be used as requirements for design purposes.

### 2-5. Outdoor Temperatures

a. Outside design temperatures to be considered in calculating the heat loss of a structure are listed in TM 5-785. The low temperature limits that are not exceeded 97½ percent of the time, on the average, during the coldest consecutive 3 months are determined by the mean dry-bulb temperature (A 99 percent limit is standard for hospitals and other critical installations.)

### 2-3. Determination of Heat Transfer Coefficients

Heat transfer coefficients (U factor) are expressed in B.t.u. per hour per square foot per Fahrenheit degree difference in temperature between the air on the two sides of the material to which they pertain. Coefficients for various types of walls, glass, ceilings, and floors are given in appendix E. They are largely self-explanatory. To select the proper factor it is necessary to know the construction, the thickness and the nature of the materials, used, and their relative location. From this information the thermal resistance (R factor) or, conversely, the heat conducting ability of the material (C factor) is used to determine the heat flow resistance (K factor). The reverse of the heat flow resistance (K factor) is the heat transfer coefficient (U factor), the amount of heat actually conducted per hour per square foot per degree Fahrenheit temperature difference through the material. The computation of coefficients for unconventional types of construction is beyond the scope of this manual. For a type of construction not found in the tables, select the coefficient for the type of construction which most nearly resembles it and add a sufficient safety factor.

Table 2-1. Winter Inside Temperatures for Design Purposes

Type of building	Temperature
Bathrooms (with tubs) .....	80° F.
Dishwashing rooms .....	50° F.
Drying rooms (parachute) .....	100° F. maximum.
Food preparation .....	70° F.
Hangars .....	50° F.
Hangar lean-tos .....	70° F.
Hydrotherapy, X-ray, etc. ....	80° F.
Issue rooms .....	60° F.
Kitchens .....	50° F.
Laundries .....	50° F.
Living spaces .....	70° F.
Offices .....	70° F.
Operating and maternity sections (exposed patients). ....	85° F.
Paint shops .....	80° F.
Shops .....	50° F. and higher.
Showers .....	70° F.
Storage (heated) .....	40° F. and higher.
Toilets .....	70° F.
Wards .....	70° F.

b. In non-critical structures, such as barracks, mess halls and shops, the 97½ percent factor should be used. This could mean that for a short period of time, possibly a day or two, usually during the early morning hours, the

heating unit will operate continuously. This will promote human comfort during the remaining 97½ percent portion of the winter by having longer operating cycles and more even temperatures in the occupied area.

### Section III. INFILTRATION LOSS

#### 2-6. Determination of Quantity of Fresh Air Admitted

Air infiltrates into buildings due to wind pressure and also due to the chimney effect resulting from the difference between inside and outside temperatures. Air may also be brought in mechanically for ventilation purposes.

a. *Air Leakage.* The quantity of air that leaks into a room or group of rooms varies with the number of windows and doors, and these, under average conditions, can be assumed to vary with the number of exposed walls. It also varies with the tightness of the windows and doors, whether or not they are weatherstripped. The quantity of air leaking into a building from natural causes can be estimated as proportional to the volume of the heated space. Data for estimating air leakage in terms of the number of air changes per hour is given in table F-1.

b. *Forced Ventilation.* In some spaces such as hospital operating rooms or assembly halls, it is necessary to bring in air mechanically from outside the building for ventilation purposes. The air introduced for ventilation should be greater than that leaking in from natural causes, for otherwise it would not be required. Ventilation systems should be so ar-

ranged that they place the building under air pressure, force air outward at the windows and door cracks, and thus prevent infiltration at these points. Because of this, when forced ventilation is used natural air leakage can almost always be neglected and the fresh air load figured on the basis of the quantity of air brought in by the ventilating system alone.

#### 2-7. Heat Required to Warm Outside Air

The heat required to warm outside air to room temperature can be determined from the formula  $Q_1 = C_p \times (T_1 - T_o)V$ , where  $Q_1$  is the heat required to warm outside air, resulting from either natural air leakage or forced ventilation in B.t.u. per hour;  $C_p$  is the specific heat of air per cubic foot at constant pressure, or .018;  $T_1$  is the inside air temperature,  $T_o$  is outside air temperature in degrees Fahrenheit, and  $V$  is the volume of air admitted in cubic feet per hour. In the example calculation of paragraph 2-1c, the average number of air changes per hour from infiltration to each room is estimated to be 1½ from table F-1. Considering the building as a whole, the total allowance for infiltration would be one-half of 1½ or ¾. The total heat loss from infiltration then becomes: 5,440 cu. ft.  $\times$  ¾ air change  $\times$  .018  $\times$  70°F. = 5,141 B.t.u. per hour.

### Section IV. ALLOWANCES FOR PIPING LOSSES AND PICKUP

#### 2-8. Piping Losses

Furnaces which supply heat through piping or duct systems from a central location must supply, in addition to the heat required to overcome the heat loss of the space, heat to replace that lost from the piping or ducts outside of the heated space. If pipes are bare, this loss may vary from 10 percent to 30 percent of the building heat loss depending on the extent of

exposed piping. Insulation of pipes or ducts will save about one-half of this loss.

#### 2-9. Pickup Allowance

Intermittently operated heating equipment, particularly boilers, must also have sufficient extra capacity to permit heating the system and its contents from a reduced temperature in a reasonable length of time. These pickup al-

allowances vary from 5 percent for automatically fired warm-air systems to 40 percent or 60 percent for hand fired steam and hot-water heating systems.

**2-10. Combined Piping and Pickup Factors**  
For purposes of boiler and furnace selection, piping losses and pickup allowances can be combined into overall selection factors. Table

G-1 gives a listing of such factors for boilers and furnaces, and these should be applied to the calculated building heat loss to determine required boiler or furnace output. Some published boiler ratings include allowances for piping and pickup, and where such ratings are used the factors in table G-1 should not be applied (para 3-2b and 4-2b).

## Section V. COMBUSTION-AIR CIRCULATION

### 2-11. Location

Fossil fuel burning equipment (using gas, oil, coal, or wood, should be located where the ventilating facilities permit satisfactory combustion of the fuel under normal operation and use. This requirement may be met by applications of the following:

#### a. Natural Ventilation.

(1) Where appliances are installed in unconfined spaces, in buildings of conventional brick, frame, or stone construction without storm windows or tight doors, infiltration is normally adequate to provide air for combustion and vent stack dilution for draft control.

(2) If the unconfined space is within a building of unusually tight construction, air for combustion and ventilation must be obtained from outdoors. Under these conditions, a permanent opening or openings having a total free area of not less than 1 square inch per 1,000 B.t.u. per hour of total input rating of all appliances should be provided.

b. *Duct Ventilation.* Where appliances are installed in confined spaces, air for combustion, ventilation, and draft hood dilution should be provided by openings communicating with areas of adequate air supply (fig. 2-2).

(1) *Air from inside the building.* The confined space should be provided with two permanent openings on the same side of the enclosure, one near the top of the enclosure and one near the bottom. Each opening should have a free area not less than 1 square inch per 1,000 B.t.u. per hour of the total input rating of all appliances in the enclosure, freely communicating with interior areas having adequate infiltration.

(2) *Air from outdoors.* The confined space

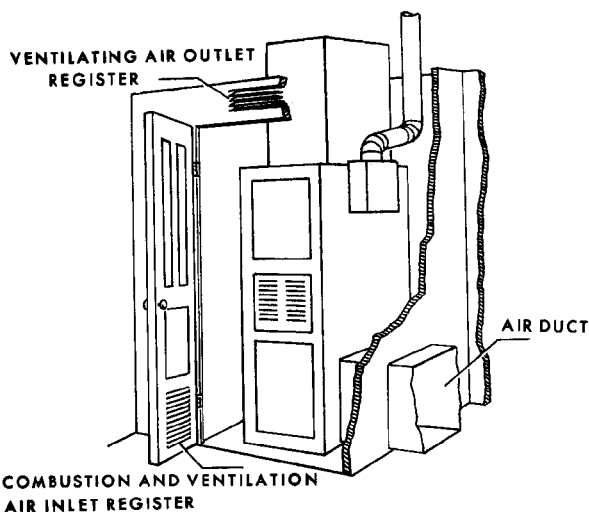


Figure 2-2. Openings necessary to supply air for combustion, ventilation, and draft hood dilution.

should be provided with two permanent openings, one in or near the top of the enclosure and one in or near the bottom directly communicating with outdoors or to spaces (crawl or attic) that freely communicate with outdoors. The openings for vertical ducts should have 1 square inch per 4,000 B.t.u. per hour total input rating, and the openings for horizontal ducts shall have 1 square inch per 2,000 B.t.u. per hour total input rating. Outdoor connections should be screened and provided with louvers.

(3) *Ventilating air from buildings—combustion and vent stack dilution air from outdoors.* The inclosure should be provided with two openings for ventilation, located and sized as described above. In addition, there should be one opening directly communicating with outdoors or to such spaces (crawl or attic) that

freely communicate with outdoors, sized on the basis of 1 square inch free area per 5,000 B.t.u. per hour of total input of all appliances in the inclosure.

c. *Exhaust Systems.* Operation of exhaust fans, kitchen ventilation systems, or fireplaces may require special attention to avoid unsatisfactory operation. When clothes dryers are exhausted to outdoors, additional air is required in order to avoid reversing the venting of other fuel-burning appliances.

d. *Ventilation Duct Sizing.* Ducts, if used as described in b above should have the same cross sectional area as the opening to which they are connected and should communicate with the source of air supply. The minimum dimension of a rectangular or oval duct should be not less than 3 inches.

## 2-12. Chimney and Flue Requirements

a. All space heating systems, steam and hot water boilers, warm air furnaces, floor furnaces, recessed heaters, and unit heaters shall be connected to an effective flue of one of the following types:

(1) Type A flues or vents are referred to as "chimneys" and made of masonry, reinforced concrete, or heavy metal pipe of leak proof construction. Type A is used for venting all boilers, space heaters, or warm air furnaces burning oil, coal, or wood.

(2) Type B is a gas flue or vent made of noncombustible, corrosion-resistant material of sufficient thickness and cross sectional area and heat insulating quality to avoid excess temperatures on adjacent combustible material. It is certified by a nationally recognized testing agency. The Type B vent is suitable for use only with vented type gas-burning appliances which produce a flue gas temperature not in excess of 550°F. at the outlet of the draft hood when burning gas at the appliance manufacturer's normal rated input.

(3) Type C vents or flues consist of round metal pipe with little or no insulating value. This type vent shall be used only for runs which go directly from the space where the appliance is located, through the roof or exterior wall to the outer atmosphere. Such flues or

vents should not pass through any attic or concealed space nor through any floor. They should be of sheet copper or not less than 24 U.S. Standard Gage or other approved corrosion-resistant material. Clearance to any combustible material should be as given in table 2-2. The clearance from a metal flue or vent connection to combustible construction may be reduced as specified in table 2-3 where the combustible construction is protected by a shield of fireproof material. The fireproof material is suspended away from the combustible material for a minimum distance of 1 inch, and the distance from the edges of the shield to the metal flue or vent is not less than the distances given in table 2-2.

Table 2-2. *Flue or Vent Connector Clearances to Combustible Material*

Appliance	Metal flue or vent connector	Type B Flue or vent connector
	<i>Inches</i>	<i>Inches</i>
Boiler .....	6	1
Warm air furnace .....	6	1
Water heater .....	6	1
Room heater .....	6	1
Floor furnace .....	9	3

Table 2-3. *Minimum Clearances When Fireproof Protection is Used*

Type of protection	Where the required clearance with no protection is:	
	6 inches, Clearance with given protection is:	9 inches, Clearance with given protection is:
¼-inch asbestos millboard with noncombustible 1-inch spacers.	3 inches	6 inches
28-gage sheet metal or ¼-inch asbestos millboard.	2 inches	4 inches
28-gage sheet metal with noncombustible 1-inch spacers.	2 inches	4 inches

b. *Outside Flues, Vents, or Chimneys.* Outside flues or vents are not recommended. They are particularly unsuccessful in severe climates and in small sizes. When they must be used, however, the material must be resistant to the actions of combustion products. It will either have high insulating ability or be well insulated with high temperature fireproof insulation such as mineral wool or fiberglass.

(1) *Support.* When a flue or vent must be installed on the outside of the building, it must be securely supported. A capped "tee" is installed at the base of the riser with an opening to drain off condensation. A suitable vent cap or H cap which does not obstruct or reduce the effective cross-sectional area of the flue or vent outlet must be placed on top of the riser.

(2) *Height.* The flue or vent should extend at least 2 feet above the point where it projects above the roof and terminate where a positive static pressure will not occur from wind action.

(3) *Size.* The area of the flue, vent, or chimney will depend upon the height of the chimney. In no case, however, will the area of the chimney be less than the area of the flue outlet of the vented appliance. Where multiple appliances are connected to the same flue, vent, or chimney, the minimum size of the flue, vent, or chimney will not be less than the area of the largest flue or vent connector plus 50 percent of the areas of the additional flue or vent connectors.

*c. Flue, Vent, or Chimney Connectors.* The flue, vent, or chimney connector is the round pipe from the flue outlet of the fuel burning appliance to the flue, vent, or chimney.

(1) *Material.* The connector must be of corrosion-resistant material of sufficient thickness to withstand damage and possess low heat

conductivity. Material successfully used for flue, vent, or chimney connectors includes metal pipe, terra-cotta pipe, cement pipe, glazed sewer pipe, and asbestos-cement pipe. Of the metal pipe, copper (16 oz.), monel metal (26 Gage), or Allegheny metal (24 Gage) are recommended.

(2) *Installation.* The flue, vent, or chimney connector should be installed so as to avoid sharp turns or other constructional features which would create excessive resistance to the flow of flue gases. The connector should maintain a pitch or rise from the appliance to the flue, vent, or chimney. A rise as great as possible, at least  $\frac{1}{4}$ -inch per foot (horizontal length) should be maintained. The horizontal run should be free from any dips or sags. The horizontal run of the connector should be as short as possible, and the appliance located as near the flue or vent as practicable. The maximum length of horizontal run will not exceed 75 percent of the height of the flue or vent. Connectors should be securely supported by means of noncombustible hangers. A connector should not be connected to a chimney having a fireplace unless the opening to the fireplace is permanently sealed.

*d. General Data.* For general data on the construction of flues, vents, or chimneys, refer to the *National Building Code, Article X.*